Digital Tachometer for Precision Machine Tools

Several LLNL high-resolution and precision diamond turning machines (DTM) rely on high-sensitivity analog tachometers for velocity-loop feedback to provide smooth machine motion at diamond-turning feed-rates. The analog velocity loop provides mass damping and smooth machine motion during the digital position loop update. Analog compensation is inflexible and costly to implement, but it provides the required dynamic range and resolution to cover machine speeds from rapid travel to diamond-turning feed-rates. This dynamic range can be greater than one million. For example, for a capstan driven DTM, rapid travel may be one revolution of the motor per minute versus less than one revolution of the motor per year at diamond turning federates.

This project is a part of an overall goal to replace aging and obsolete machine-tool controllers on several LLNL precision machines. A modern controller will reduce machine maintenance costs and allow greater machine capability. Replacing the analog velocity loop with a digital loop simplifies the cost of a machine retrofit.

Our approach is to digitize the analog tachometer with sufficient resolution for direct input to the new controller. The conversion must be able to handle a dynamic range of 20 bits or greater for the controller to properly provide digital compensation of a velocity loop. In addition, the converter must be monotonic as it is used in a servo loop. A delta-sigma A/D converter has sufficient number of bits and monotonic behavior.

Project Goals

The goal is to digitize the analog tachometer signal and provide the synchronization and data formatting for the machine-tool controller (Fig. 1). Additionally, it is desirable to connect

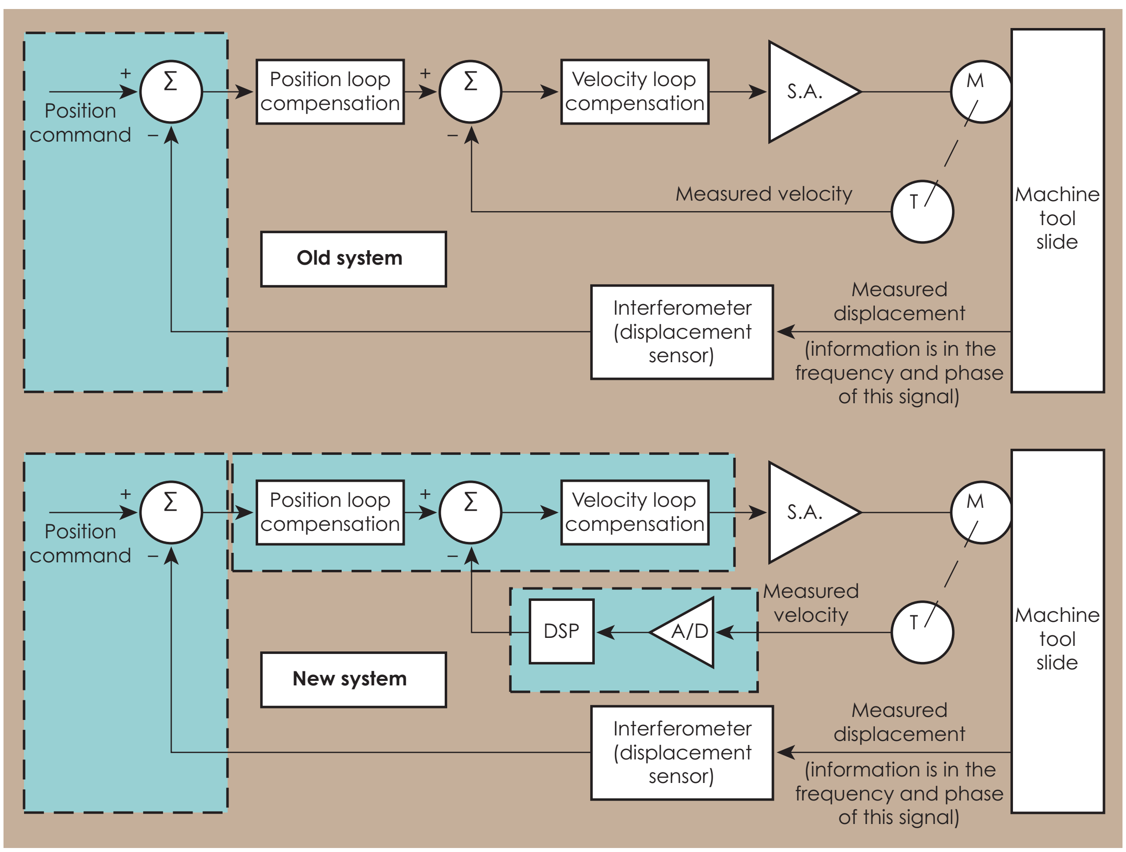

Figure 1. Block diagram comparison between the old and new systems. The green highlighted background indicates the digital implementation.

For more information contact
David J. Hopkins
(925) 423-6134
hopkins3@llnl.gov

the system to a precision machine and show smooth machine-tool motion at diamond-turning feed-rates. The project is to produce a set of documentation and software algorithms for implementing this approach on any tachometer-based machine tool.

Relevance to LLNL Mission

The project will add to the tools available to upgrade precision machine tools and help the learning curve for using a new machine-tool controller. This project also indirectly supports target fabrication, NIF optic fixtures, and NAI.

FY2005 Accomplishments and Results

An off-the-shelf PC-based digital signal processing (DSP) board was selected for the test-bed hardware. The converters on this board can run at effective sample rates of up to 192 kHz. The processed converter signal is sent to a 24 bit I/O port of the DSP board and then connected to the digital input port of the machine-tool controller.

The software environment is TI Code Composer Studio. C++ code was written to configure the converters and I/O port, and to set up the machine-tool controller. The code is a multi-threaded application and allows changes in sample rate and enabled channels during testing. Also included in the code, is the ability to activate multiple second-order bi-quad filters to filter the sampled A/D data.

The ideal results of this project would be to obtain several kHz of frequency response from the system. This would minimize phase delay in the velocity loop and allow this system to approach the bandwidth limitations of the machine controller. Unfortunately, the measured transfer function (machine controller output vs. tachometer input) is only a few hundred Hertz (Fig. 2). The bandwidth limitation is due to the inherent delay in the delta-sigma converter and the delay caused by DSP board architecture. The system is usable for low-bandwidth machines but is limiting for some higher performing machines.

This project has proven the approach works, but increasing the bandwidth by using a different processing architecture would be desirable.

Related References

1. Bowling, S., "Understanding A/D Converter Performance Specifications," *Application Note AN693, Microchip Technology, Inc.*, 2000.
2. "PCM1804 Full Differential Analog Input 24-Bit, 192-KHz Stereo A/D converter," *Texas Instruments Data Sheet*, Burr-Brown Products from Texas Instruments, Texas Instruments Inc., 2001-2005.
3. Technical Staff, "Delfin User's Manual," Innovative Integration, 2003.
4. "Code Composer Studio, Getting Started Guide," *Texas Instruments SPRU509C*, 2004.

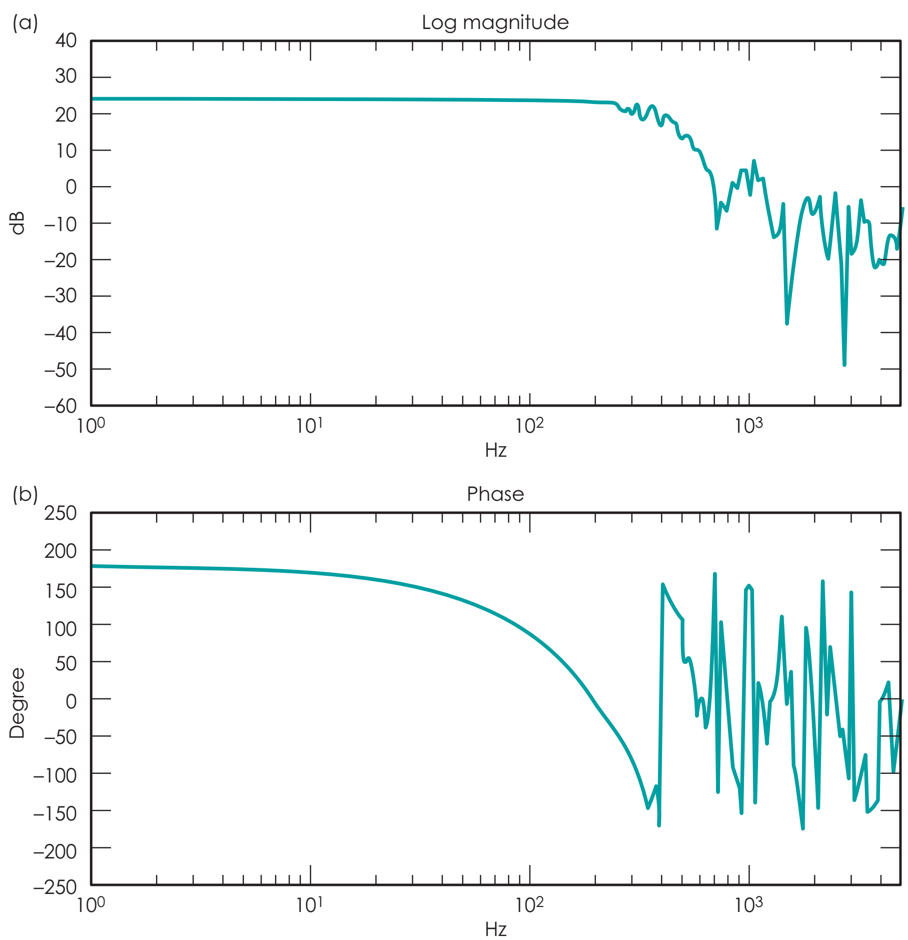

Figure 2. Measured transfer function: (a) gain, and (b) phase.